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THE START OF HIGH POWER MICROWAVE RESEARCH AT THE AIR FORCE WEAPONS LABORATORY

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Final Report

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This report is a brief history of the beginnings of the High Power Microwave Program at the predecessor organization to the Air Force Research Laboratory, i. e. the Air Force Weapons Laboratory at Kirtland AFB, New Mexico. The program grew out of concern for the vulnerability of electronics on Air Force systems in the early 1980s. The more sophisticated the solid state electronics and integrated circuits employed by the Air Force became, the more susceptible they were to upset and damage from electromagnetic radiation from a variety of sources, including high power microwaves. The Air Force Weapons Laboratory was poised to take on this new technology challenge from its decades of research on nuclear electromagnetic pulse and its effects on electronics.

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TABLE OF CONTENTS

1. ABSTRACT

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2. NARROWBAND HIGH POWER MICROWAVE RESEARCH

The narrowband High Power Microwave (HPM) program at the Air Force Research Laboratory (AFRL) had its beginnings from one of its predecessor organizations, the Air Force Weapons Laboratory (AFWL), at Kirtland AFB, NM. In the late 1970's and early 1980's, the main technology areas at AFWL were high power lasers and nuclear weapons' effects (organized within ARTO, the Advanced Radiation Technology Office, and NTO, the Nuclear Technology Office). Transient Radiation Effects on Electronics (TREE) was one of the areas that scientists at AFWL/NTO studied during this period. Another effect of prominence that was studied in detail was the nuclear electromagnetic pulse (EMP). This naturally led to a keen awareness of the increasing susceptibility of Air Force electronics systems from electromagnetic radiation. Furthermore, simulators

that employed high current electron beam devices had been built at AFWL to study these effects.

At about the same time various analysts were considering using microwave radiation as a weapon as well as for communications and detection. But until the 1980s damage thresholds were high compared to available microwave output power. Then, two technological trends changed the situation. First, development of sources of microwave power in the gigawatt range posed a plausible threat to military equipment. Second, the military grew increasingly dependent on microelectronics that were susceptible to upset or burnout at much lower power levels than their predecessors.

These two developments suggested that HPM (meaning at the time devices with outputs in excess of 100 MW) might play important roles on future battlefields. They might perform traditional electronic warfare missions such as jamming enemy radar and command and control systems, but that was not all. They might also disable enemy aircraft and missiles in the air or on the ground, thus contributing to a wide variety of offensive and defensive missions. Planners thought that HPM uses could range from air base defense, aircraft self-protection, and suppression of enemy air defenses to attacks on airfields, imprecisely located or "strategic relocatable" targets (mobile missiles and command posts), and satellites.

But while analysts expected that HPM would have significant military potential, they could not be sure. Whether HPM would be useful military weapons depended on many unanswered questions. How did microwaves cause damage? Were pulsed or continuous wave microwaves more lethal, and against which types of targets? Were pulses with fast rise times more dangerous than pulses with slower ones? Was peak power more

important than total energy delivered? Were some frequencies more lethal than others? How vulnerable was military equipment to microwave attack? What effects did microwaves have on human beings? How could successful microwave attack be verified; i.e., were reliable kill assessment techniques possible? Could shielding and other counter measures reduce vulnerabilities to the point that HPM weapons would not be worth the investment?

AFWL began exploring these technology issues in June 1983. The effort began as a small initiative with two scientists. It centered on modifying a Physics International (PI) pulser as a virtual cathode oscillator and using it as a tunable HPM source. The new machine was capable of 1 GW pulses with a rise time of 1.3 ns and a pulse width of 2.5 to 25 ns. The frequency could be tuned between 3 and 10 GHz. Over the next few years, a variety of pulser/source configurations were built on mobile platforms at AFWL provided the U. S. with the first mobile source of gigawatt microwaves.

While experiments in source development were being conducted by all three services in the DOD, deliberations in Washington were focusing the attention by leaders on HPM. The AF Scientific Advisory Board (SAB) conducted a study in the summer of 1985. The recommendation of this panel was that a coordinated program in HPM technologies be started. The goal of this effort was not to develop a weapon; instead, it was to determine whether HPM could have important effects (both positive and negative) on Air Force missions. The program would gather information on damage mechanisms, lethality, the vulnerability of U. S. and foreign systems, the effects of HPM on people, and possible countermeasures.

At about the same time that the SAB made these recommendations, a major Air Force study on future systems and technologies the Air Force needed to operate in the early twenty-first century was just being finished. In this Forecast II report, HPM was ranked as one of the top five technologies that the Air Force should develop. Thus, during the mid-1980's, the AFWL started to invest considerable resources into developing HPM sources and modulators to drive them.

The Air Force (and AFWL) started to shift away from nuclear weapons effects as it approached the decade of the 90's. During various re-organizations of AFWL (absorbed by the Phillips Laboratory and then made a component of the single laboratory, the AFRL), a significant research effort was concentrated on "Advanced Weapons." The HPM program became an integral part of this strategy, adding ultra-wideband sources to its repertoire.

3. ULTRA-WIDEBAND HIGH POWER MICROWAVE RESEARCH

Ultra-wideband (UWB) sources and antennas were also a natural outcome of EMP research at AFWL. A well-established research program to design and build EMP simulators started in the late 1960's. These devices produced transient electromagnetic radiation similar to the nuclear EMP that threatened Air Force systems during the cold war. The simulators consisted of pulsers and antennas of various configurations and were developed under the guidance of the AFWL's Dr. Carl Baum, now the Senior Scientist for Electromagnetics at AFRL, a true visionary and international pioneer in transient antenna design.

Thus, UWB HPM research grew out of EMP expertise at AFWL. It was recognized that as the technology improved pulsers and switches could be built in smaller packages. The pulser improvements came in the form of faster rise time breakdown (sub-nanosecond). Hence, transient, repetitive pulses could be generated in the microwave portion of the electromagnetic spectrum. A variety of potential applications for these systems, ranging from transient radar systems to communications systems, were envisioned.

The research into UWB transient antennas, first at AFWL (now AFRL/DE, the Directed Energy Directorate of AFRL) and in other groups around the world, has also contributed significantly to the development and improvement of extremely wideband continuous wave (cw) and non-dispersive antenna designs. The approach at AFRL included two thrusts involving gas switched sources: very powerful, high pressure hydrogen spark gap pulsers and compact hydrogen gas switches in conjunction with high gain UWB antennas. This research started in the early 1990's with the H-series (hydrogen series) of pulsers. Over the last several years, improvements in high voltage insulating oil and short-pulse gas switching have allowed significant gains to the UWB technology.

The Air Force Research Laboratory also pursued arrays of solid-state switched UWB pulsers and antennas. This work, begun in the late 1980's, started with the use of photoconductive solid state switches using GaAs technology. These arrays, in fact, presently hold the record for peak radiated field strength in the far field of the antenna.

4. SUMMARY

High Power Microwave research was begun at the AFWL and continues on at its successor organization, AFRL/DE, to meet a need that came about from the Air Force's dependence on sensitive electronics and their potential vulnerability to electromagnetic radiation. Improvements in relativistic electron beam devices and the generation of gigawatts of pulsed power paved the way for gigawatt-class narrowband microwave tubes in the decade of the 1970's and 1980's. In addition, fast solid state switches, transient antenna designs, and gas breakdown research allowed the AFWL to build megawatt (and then gigawatt) ultra-wideband sources. These two components comprise today's AFRL HPM microwave source research program.

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